Guide

to the

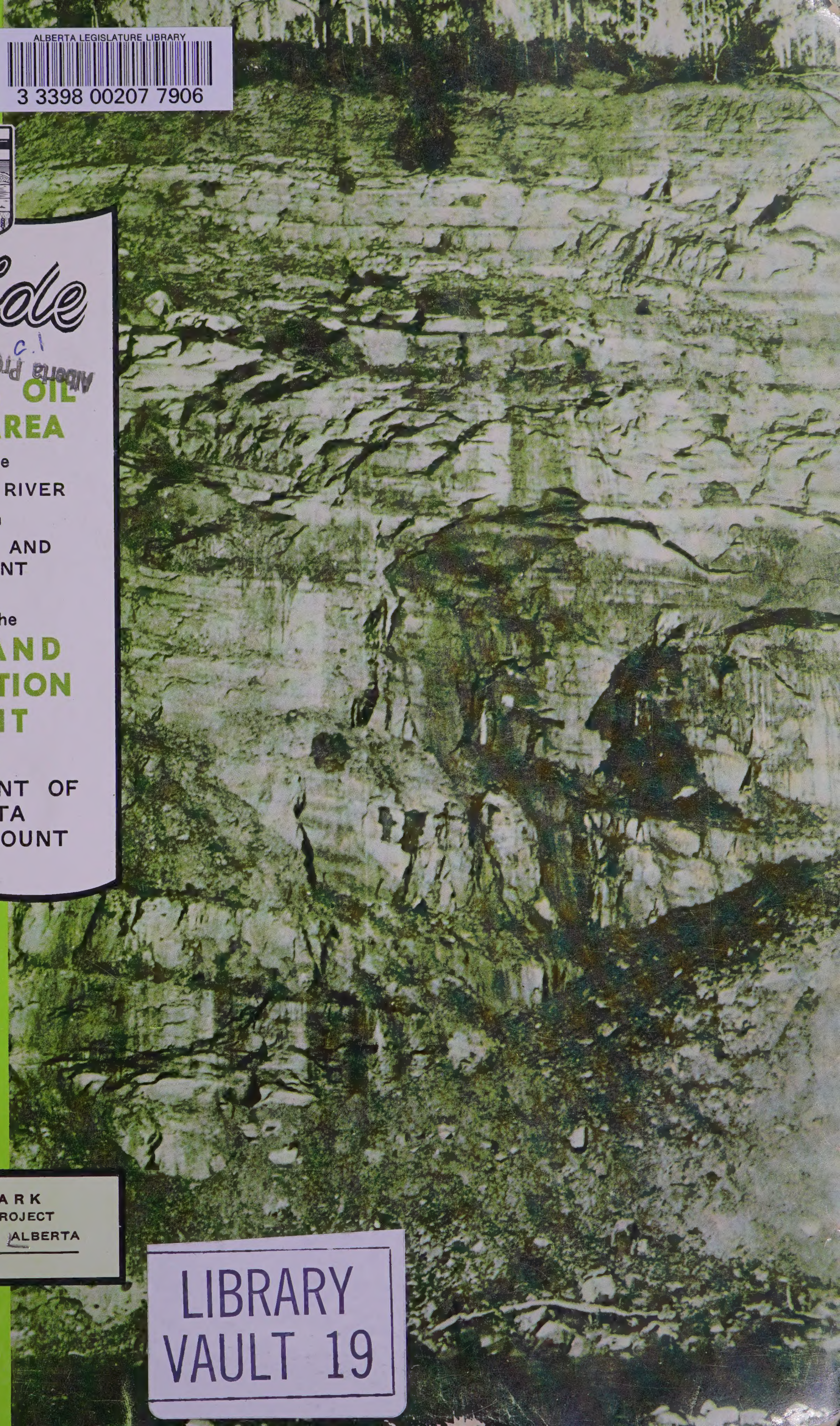
ALBERTA OIL SAND AREA

along the
ATHABASCA RIVER
between
McMURRAY AND BITUMOUNT

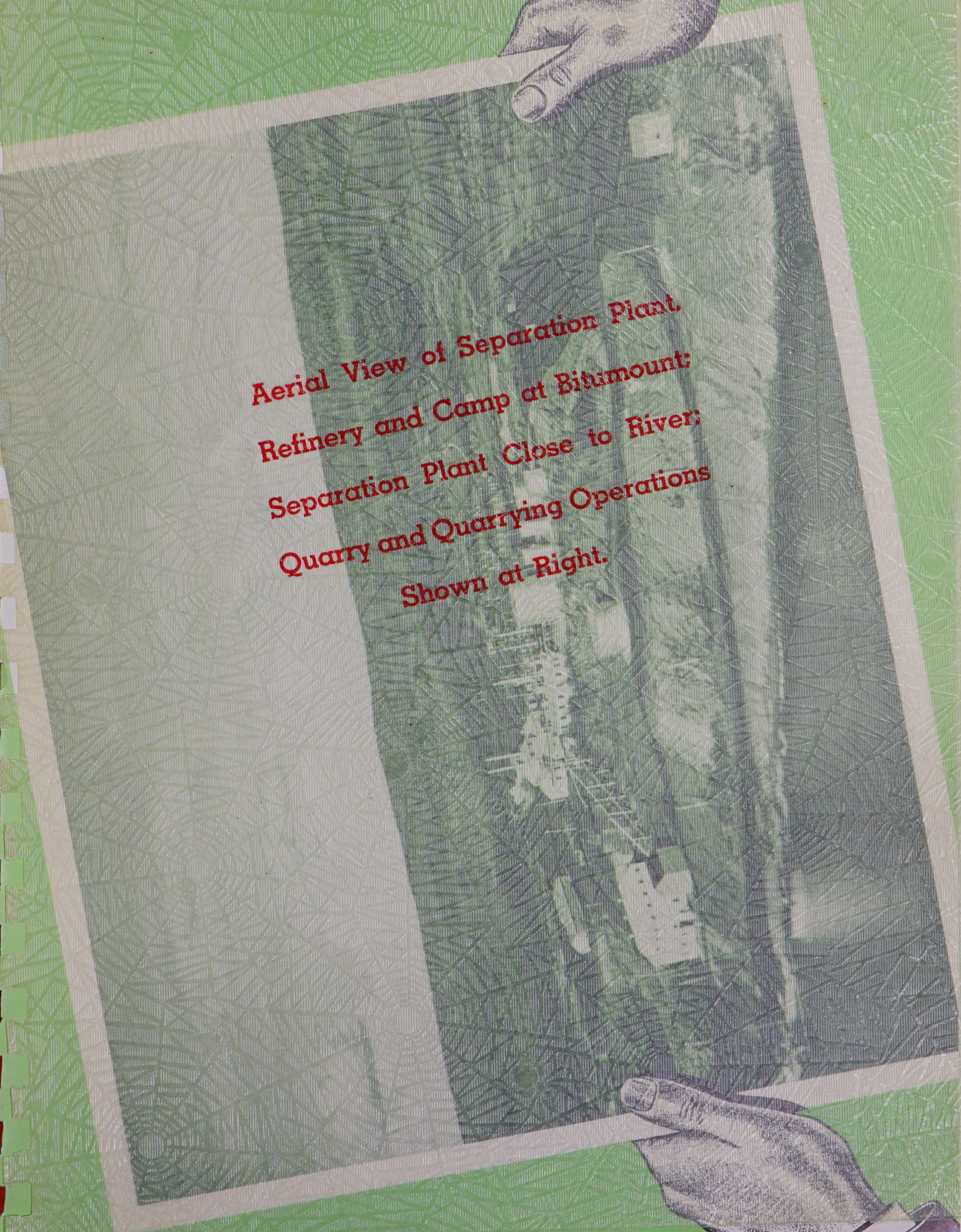
and to the

OIL SAND SEPARATION PLANT

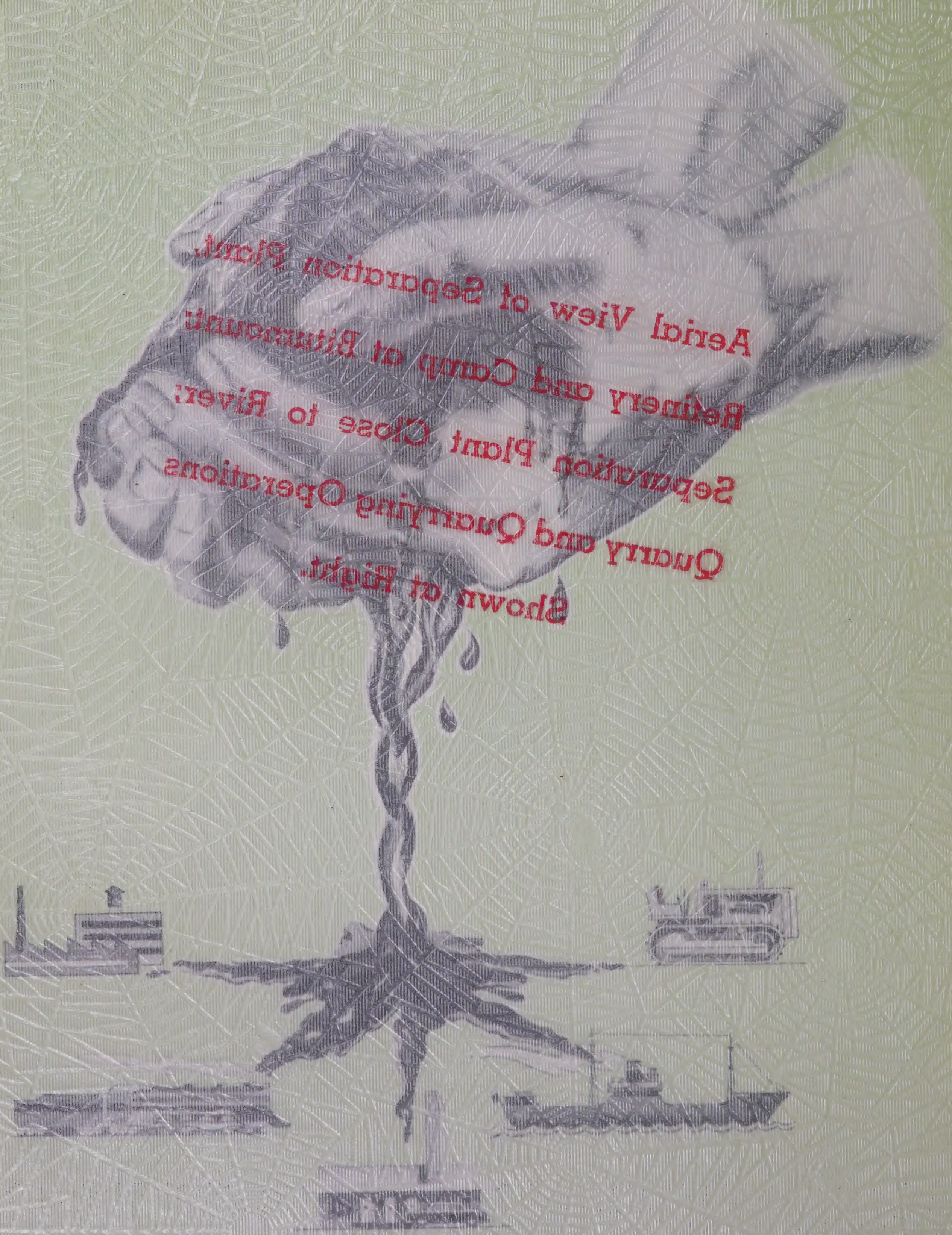
of the
GOVERNMENT OF ALBERTA
AT BITUMOUNT

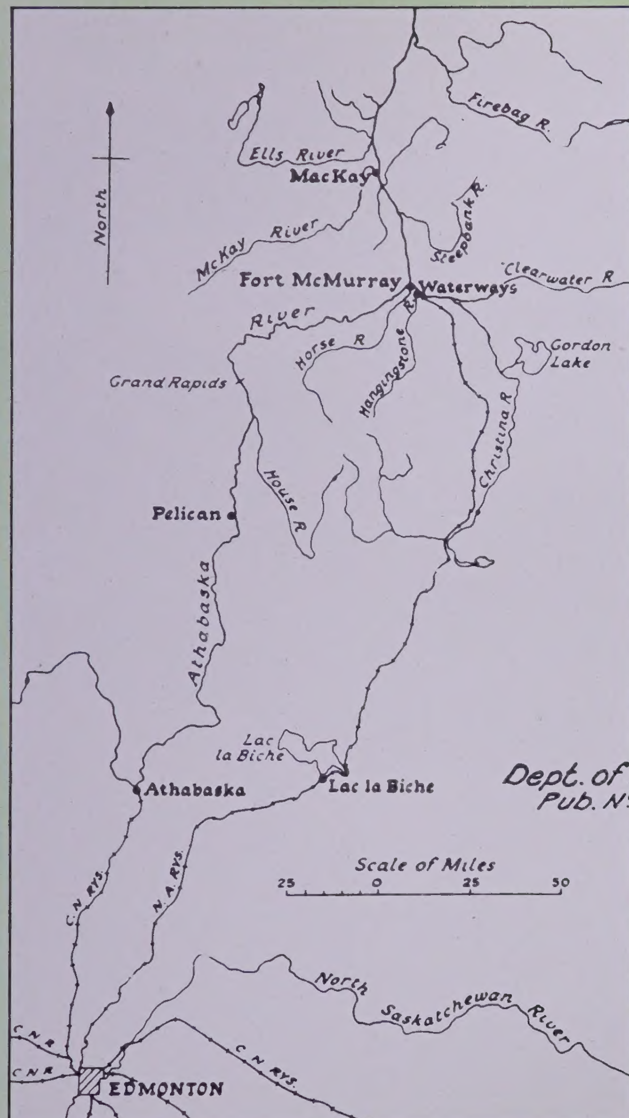


K. A. CLARK
OIL SANDS PROJECT
GOVERNMENT OF ALBERTA
1951



Aerial View of Separation Plant, Refinery and Camp at Bitumount; Separation Plant Close to River; Quarry and Quarrying Operations Shown at Right.

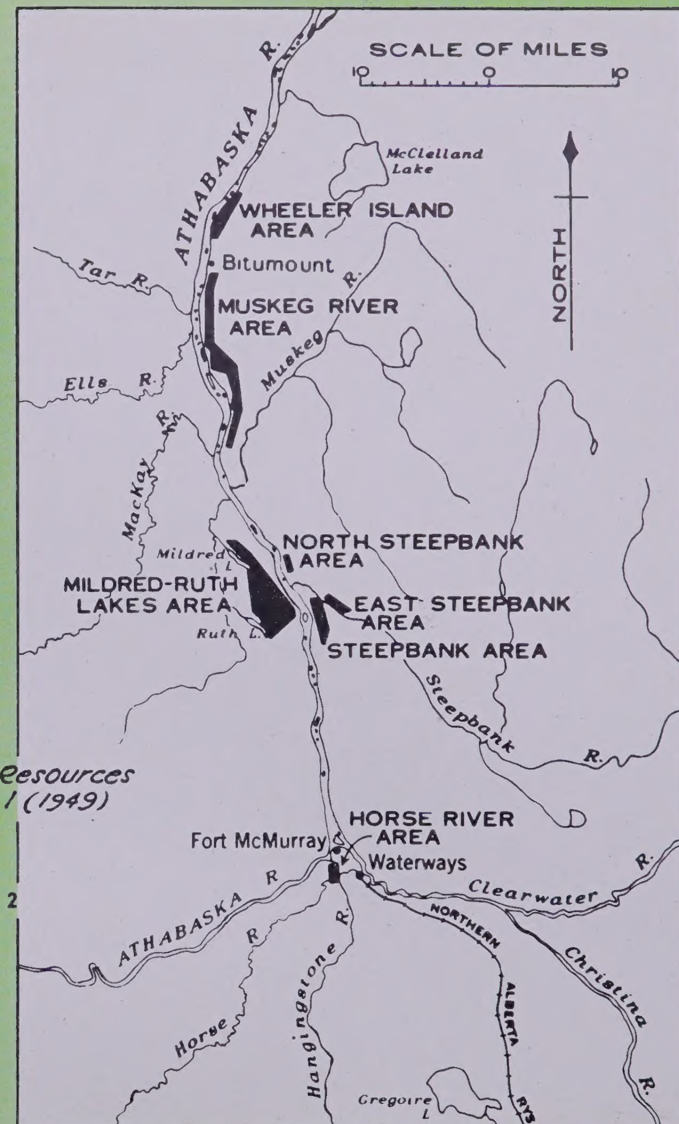




KEY MAP SHOWING RELATION OF FORT McMURRAY TO EDMONTON, ALBERTA.

Dept. of Mines & Resources
Pub. N° 825 Vol I (1949)

FIGURE I - 2



KEY MAP SHOWING AREAS EXPLORED BY DRILLING SINCE 1943.

Visit to McMurray and Bitumount

THE PURPOSE of this booklet is to assist visitors in acquainting themselves with the country in which the Alberta oil sands occur, with the oil sand formation and with the development work that has been done at the plant of the Province of Alberta at Bitumount. The journey north is best made by plane. During the flight to McMurray airport, the gradual change in the nature of the country from farmland around Edmonton to muskeg and sand ridges north of Lac La Biche can be noted. The town of McMurray is 12 miles by road from the airport. It is at the junction of the Clearwater river with the Athabasca river. There is a high cutbank of oil sand lying on Devonian limestone along the Athabasca river at McMurray. Other exposures can be seen in the valley of Horse River nearby. The site of the Abasand Oil Ltd. plant is in Horse River valley a mile by trail or several miles by road from McMurray. Oil sand exposures occur all along the Athabasca river. These can be seen on the flight between McMurray and Bitumount. The limestone close to the water level of the river is a noticeable feature of the Athabasca valley. At Bitumount good grade oil sand is exposed to view in the quarry. The separation plant can be examined in detail. The dehydration and distillation equipment, although not conforming to the sequence of operations proposed in the Blair report, is of interest.

EDMONTON TO McMURRAY AIRPORT

The country lying between Edmonton and McMurray is of interest in its own right and also because the pipeline for a bituminous sand development would pass through it. In the vicinity of Edmonton the scene is one of well developed farmland. The Redwater oilfield lies about 30 miles to the northeast. Proceeding northward, the farms thin out. The reason, it will be seen, is that muskeg is occupying more and more of the surface. Farmers set fire to the muskeg and when all that will burn is consumed, they plow the remainder into the underlying clay. They extend their fields in this way. However, muskeg becomes more and more prevalent northward and farming ceases in the neighborhood of Lac La Biche. Further north the country is a wilderness of muskegs and sand ridges. It is much more interesting to fly over than to walk through.

The oil sand formation extends southward from McMurray but how far is not yet known. The Geological Survey well (1898) at Pelican Rapids and a recent exploratory well about 75 miles south of McMurray encountered the formation at about 900 feet depth. Wells 75 miles west of Pelican Rapids also passed through oil sand at about 2,000 feet depth. Oil sand exposures appear east of McMurray on the Clearwater river. But at Cottonwood creek, 25 miles upstream, the sand is found to be devoid of oil. Apparently oil impregnation of the formation does not extend far east of the Athabasca river. It is interesting to ponder, as one flies toward McMurray, that the country, as far as the eye can reach is underlain by the extensive oil sand deposit.

McMURRAY

The town of McMurray grew around the trading post of the Hudson's Bay Company — Fort McMurray. The post was on the river bank at the foot of the main street of the town. The buildings have disappeared. The post was established in 1870 in anticipation of the use of steamboats by the company for river

transportation. There are rapids on the Athabasca river above McMurray, but navigation is uninterrupted downstream to the boundary of the province. The first of the steamboats, shallow draft stern wheelers, was built in 1882 at Athabasca Landing on the Athabasca river about 100 miles north of Edmonton and was brought through the rapids for service on the river north of McMurray. The original canoe route of the fur trade into the Athabasca and Mackenzie region was across Methy Portage from the headwaters of the Churchill river to the Clearwater river. Fort McMurray was an important point on this route during the latter years of its use. The oxen for hauling carts across the 12-mile portage were wintered on the "prairie" — a natural meadow area between McMurray and Waterways. The building of the Canadian Pacific Railway, which reached Edmonton in 1891, made the Methy Portage route and method of transportation obsolete. The trade route then was from Edmonton to Athabasca Landing by road, down the Athabasca river by steamer to the head of the rapids, and through the rapids by barges to McMurray. The town of McMurray had its beginnings at about this time. Pilots for taking the small barges through the rapids landed at McMurray and walked back by trail for another trip. This activity ceased with the completion of the railway to Waterways in about 1922. The steamboats were a picturesque feature of the river up to the outbreak of the last war. They burnt cordwood, cut and piled at convenient intervals on the river bank by trappers. Diesel-powered boats displaced the steamers. The last of them, the S.S. Athabasca, was kept in service during the war and then dismantled.

McMurray was an important base for pontoon planes around 1930 when prospecting of the north country by means of them was in its beginnings. Planes are still in evidence on the "sny". However, during the war, airports for wheel planes were established throughout the north. The McMurray airport was built at this time.

McMurray had a place in the war effort. Great quantities of materials and equipment for the Canol pipeline were shipped to Waterways. The "prairie" was filled with barracks for American work troops and with supplies of all kinds. A tent for military police stood at the corner near the hotel in McMurray. White and black soldiers alternated in spending off-duty time in town.

The old fur trade of the Hudson's Bay Company still goes on throughout the North. Wartime projects belong to the past. The main activity now is mining — uranium on Great Bear Lake, gold at Yellowknife on Great Slave Lake and more uranium at the east end of Lake Athabasca. The time is approaching when an oil sand industry along the Athabasca river will become a major item in the development of the north country.

OIL SANDS AT McMURRAY

The oil sand area of immediate significance from the standpoint of development lies along the Athabasca river for about 70 miles north of McMurray. The formation here outcrops in the banks of the main and tributary rivers and lies under a mantle of sand and clay varying from a few feet to 150 feet in thickness. It is of Lower Cretaceous age and lies unconformably on a floor of Upper Devonian limestone. The oil sands are 150 to 175 feet thick.

An imposing cutbank of oil sand and of the underlying limestone occurs along the Athabasca river starting just upstream from the site of the old fort at McMurray and continuing for a quarter of a mile to the mouth of Horse river. The exposure shows off well

the thickness of the formation. Much of the section consists of beds of poor grade material.

The are other cutbanks along Horse river. There was once a large lens of high-grade oil sand here. It was about 75 feet thick lying on the limestone. Most of this lens was eroded away during the formation of Horse River valley. The remnant underlies the valley flats. The Abasand Oils Ltd. quarry and plant was in Horse River valley about a mile from the mouth. The plant has been dismantled.

THE ATHABASCA RIVER

A rapids can be seen on the Athabasca river at the bend upstream from McMurray. This is the last of a series of rapids extending for about 85 miles. Below McMurray the river has a current of about three miles per hour. Conditions are favourable for sandbar formation and the river is full of them. The deep channel follows a tortuous course that makes changes along its way from time to time. There is navigation by power boat and barges from McMurray northward to Lake Athabasca and beyond to the boundary of the province near Fort Fitzgerald. Navigation is interrupted here by rapids. A sixteen-mile road must be used to reach navigable river again at Fort Smith. There are no further interruptions to navigation right through to the Arctic Ocean.

The top of the Devonian limestone is well above river level at McMurray. It continues in view for more than 40 miles to past Fort MacKay. It is higher above river level at some places than at others. The oil sand with the limestone below can be seen frequently. Low limestone cliffs along river flats contribute a picturesque touch to the scenery along the river. Below MacKay the limestone disappears from view. At Bitumount it is 100 feet or more below river level. It reappears on the west shore about five miles below Bitumount.

At McMurray the banks of the river valley rise quite abruptly. High oil sand cutbanks occur. Going downstream, the valley broadens and the rise to the general country level becomes more gradual.

The first sizable tributary entering the Athabasca from the east is Steepbank river. Its mouth is about 20 miles below McMurray. Core drilling has revealed several bodies of high-grade oil sand near Steepbank river that occur in a way that is favorable for mining. The Mildred-Ruth Lakes area lies on the west side of the river. This is the most favorable area for development so far found by coring. However, only a good start has been made on exploratory drilling.

BITUMOUNT

The Quarry

The river bank at Bitumount rises about 65 feet above water level. This bank is oil sand of good grade. There is evidence that the top of the bank is at the top of the oil sand formation and that the formation goes below river level for over a hundred feet to the limestone floor. No core drilling has been done in the vicinity of Bitumount. At the top of the bank the overburden of sandy soil, shell rock and weathered oil sand beds is only about 8 feet deep. This condition extends back for several hundred feet. The ground level then rises due to thickening overburden. The quarry was opened in the easy overburden conditions along the top of the bank. The top beds mined contained about 11% oil by weight. The oil content increased to 15% at lower levels.

The showing of oil on the stripped surface of the quarry area is interesting. It is due to ground water working through the top beds displacing oil. Seepage oil is found at many points throughout the oil sand area. It is al-

ways associated with water emerging from oil sand beds.

The oil sand was dug directly from the face of the quarry by a ¾-yard power shovel. This was done during the spring and summer months, and digging was confined to the zone of material affected by the warm weather. The shovelman developed a face about 10 feet high. When asked why he did not go deeper, he said that the oil sand was frozen further down. Actually, the temperature obtained by lowering a thermometer into a three-foot auger hole bored from the shovelman's "frozen" floor was 42° F. A temperature measurement in a diamond drill hole in the Mildred-Ruth Lakes area at 200 feet depth was 36° F. The oil sand is an unconsolidated sand aggregate cemented with a viscous oil. The viscosity of the oil increases rapidly with decreasing temperature and, conversely, becomes much more fluid and a weaker cementing agent as the temperature rises. Consequently, a small power shovel is able to dig the oil sand at Bitumount directly from the beds quite readily when the temperature of the sand is above, say, 45° F. At the Abasand plant near McMurray, even in summertime, a shovel would not dig effectively without first shattering the oil sand beds by light blasting. This is because the oil sand becomes progressively more viscous going southward from Bitumount along the Athabasca river. In large scale mining at any location the surface layer of material affected by either warm summer or cold winter weather would have little significance. Mining in all seasons would be concerned with oil sand beds at about 40° F. This thought should be kept in mind when examining the Bitumount quarry. Impressions gained from the appearance and feel of warmed surface material can be misleading.

Separation Plant

The Alberta oil sands are very amenable to washing with hot water for recovery of their oil content. The operation is a simple one. The oil sand is mixed and heated with water to a pulp containing 12% to 15% of water. This pulp is then flooded in excess hot water. The oil separates from the sand and floats to the surface as a buoyant froth. The sand sinks. Fine mineral matter and some oil in fine fleck form becomes suspended in the plant water. The oil froth is skimmed from the surface of the plant water; sand tailings are removed by suitable mechanical means; and the load of sediment in the plant water is kept within bounds by some form of settling. The hot plant water is circulated with addition of make-up to replace water going out with the tailings. The hot water washing process is described in pages 19 to 22. A detailed flowsheet of the Bitumount separation plant is shown on page 25.

The storage hopper at the head of the plant is interesting. The feeding of a material like oil sand from a hopper looks like a difficult problem, but the hopper works well. Its action centres on the perforated steam pipes just above the discharge openings of the hopper into the screw conveyors below. When steam is shut off, the oil sand bridges and the downward movement of sand ceases. On applying steam pressure, the bridging is kept broken and oil sand moves downward steadily as the conveyor carries it away. The steam also heats the oil sand. In fact, this is the way to get the pulp up to the desired temperature of 185° F. The steam-jacketed conveyors and pugmill do little more than maintain the temperature. The storage hopper works. But further study of the factors at work is needed for intelligent design of hoppers of large throughput.

Oil sand was brought from the quarry in trucks that dumped their loads onto a grating with six-inch openings covering the top of the storage hopper. The material as excavated

contained lumps of oil sand. The lumps lay on the grating until they collapsed of their own weight, sometimes with a little help. As the weather became cooler in the autumn, lumps became more prominent in the oil sand coming to the storage hopper and they did not disintegrate and fall through the grating without a lot of help. It seemed obvious that for winter operation a suitable crushing plant would be required. Very little stony material occurred in the Bitumount quarry.

The various parts of the separation plant are of simple design. The flowsheet should make them easily understood. Attention may be drawn to what is termed the "sand distributor". It is here that the effective separation of oil from sand takes place. The circulating plant water enters the distributor in a manner that causes turbulence but only slight entrainment of air. The oil sand pulp drops from the pugmill into the turbulent water stream and is completely disintegrated. The oil forms a froth with water vapor supplemented by enough air to raise the pressure to that of the atmosphere. Sand and froth are swept into the large body of water in the separation cell where they sink and float, respectively.

The continuous settling tank into which the oil froth flowed from the separation cell was provided in the design to settle sand from the oil in case it proved to be sandy. If the plant followed laboratory performance there would not be much sand. On the other hand, all former separation plants in the north had produced very sandy oil froths. Actually the mineral content of the oil froth ranged between 4% and 8% and most of this was silt and clay. So the settling tank was functionless. It would not have functioned in any case since there was not a sufficient drop in temperature to cause the froth to collapse. Sand does not settle out of an oil froth.

The separation plant gave better results than were obtained in laboratory work. The sand content of the froth was low as has been mentioned. The recovery of oil was 90%. In laboratory work recoveries were around 80%. The reason for the better recovery in the plant was that freshly mined oil sand was being worked with. Oil sand deteriorates, from the standpoint of separation, when kept in storage.

The 10% of oil that was not recovered became dispersed as very small flecks in the plant water. It settled along with fine mineral matter in the plant water settler. Half of it could be recovered by passing the underflow from this settler through a conventional mineral flotation cell.

An interesting and practical point is that the fine mineral matter carried by the plant water coagulates. Consequently, it settles readily.

The separation plant at Bitumount is of simple design. But it could be simplified still further. The inclined screw conveyor for removing sand tailings from the separation cell was a cumbersome arrangement. It was used because all former plants had inclined screws and the designers were reluctant to depart from precedent. Work at the Research Council of Alberta indicates that the separation cell could be of circular construction with oil froth overflowing a lip as in a Dorr thickener and with sand tailings flowing from a bottom cone discharge at 70% solids into the suction pipe of a sand pump. This pipe would also conduct a raw water flow that would be controlled by variations in the sand level in the separation cell. Sand tailings would be discharged to waste at about 30% solids. A rake in the separation cell would bring the sand over the central discharge and would provide means for an automatic sand level control. A control for the water-oil froth interface would be needed also. The load of sediment in the

plant water could probably be kept sufficiently low by use of a Driessen cone. Within wide limits, dirty plant water has little effect on the performance of the process.

Dehydration of Wet Separated Oil

The dehydration and refinery units at Bitumount have little significance. The operations they performed are not included in the sequence of operations proposed in the Blair report. However, they are of some interest.

The Bitumount plant was built to demonstrate the practicability of the hot-water separation process for recovering oil from the oil sand. The processing of the oil was not under study. However, the elimination of water and coarse mineral matter from the wet oil product of the separation process had to be accomplished for two reasons. In the first place, the hot-water process was of no use if its oil product could not be got into usable form for refining. In the second place, fuel oil for the power plant had to be obtained to keep the separation plant running.

At the time the Bitumount plant was designed, the only sure method available for eliminating the high content of water from the wet separated oil was the one that had been used at the Abasand plant. This consisted of mixing the wet oil with as light a distillate as was available to reduce both the gravity and the viscosity and then to settle the diluted crude. Water and mineral matter settled out to a degree that was dependent on the extent of the dilution and the length of the settling period. At the Bitumount plant the wet oil was pumped from the separation plant, up the hill to the refinery area. Here it was mixed with hot distillate amounting to about 50% by volume of the actual oil in the wet crude. The diluted crude was passed through a continuous settler. Considerable mineral matter and water settled out but the overflow from the settler still contained about 15% water. The overflow was pumped through a heater in which the water present was converted to steam. The resulting oil-steam foam was passed into a steam separator. Practically dry oil was obtained in this way.

This method of eliminating water was not regarded as a good one but it was, as has been said, the only method known at the time. The addition of distillate, that had to be recovered by distillation, to the crude oil was not desirable. Also, stubborn emulsions formed in the continuous settler and went out with the underflow. A serious loss of oil resulted. However, the method served its purpose of cleaning up the wet separated oil so that fuel oil could be prepared from it.

The pressure settling vessel shown in the flowsheet was an idea of the designers. Such vessels are used in certain refineries to eliminate water from crude and it was thought that it might work at Bitumount. Laboratory work at the Research Council of Alberta indicated that the scheme was not applicable to wet oil-sand oil. It worked no better at the plant than in the laboratory.

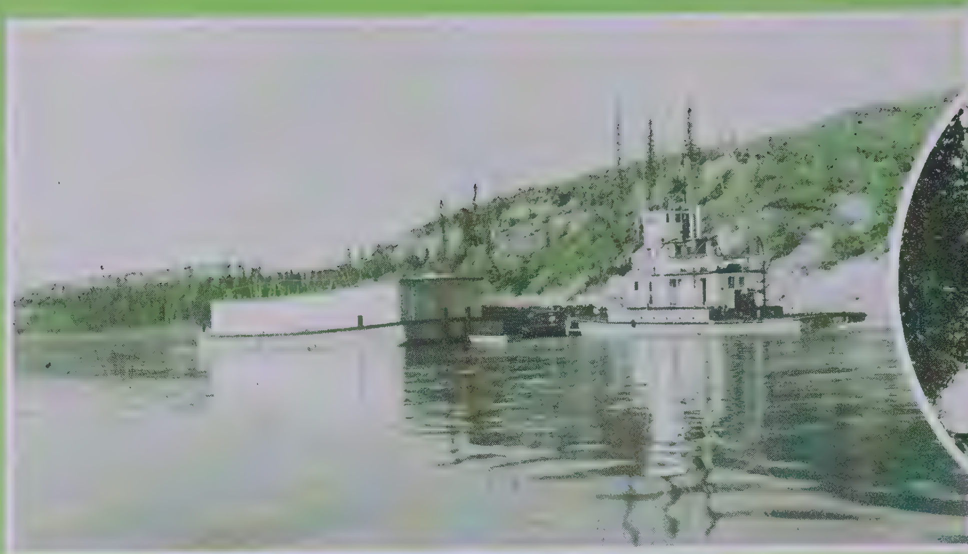
Refinery

The refinery was of the simplest sort. The dry diluted crude oil was heated to 825° F. and passed into a flash chamber. The vapors from this chamber passed into a fractionating column. All distillates collected from the column were combined and used for diluting the wet crude oil. The combined bottoms from the flash chamber and column were used as fuel. There was some difficulty in establishing conditions in the refinery that would result in recovery of all the distillate added to the crude along with enough new distillate to cause the supply to build up and yet have a bottoms product that was not too heavy to handle in the piping and pumping system provided. The

difficulty was met, at least for summer operating conditions. Only a small part of the bottoms were needed for fuel. The balance went to storage. There is plenty of it on hand to start up the plant again.

In the Blair report it is proposed to feed the wet crude oil from the separation plant directly to a fluidized solids continuous retort. The products would be a fluid coker distillate, gas and coke. The coke would be consumed in the burner of the retort. The gas would be utilized as fuel. The coker distillate, after desulphurization by mild hydrogenation, would be the final product for marketing.

Discharging Sand Tailings to Waste.

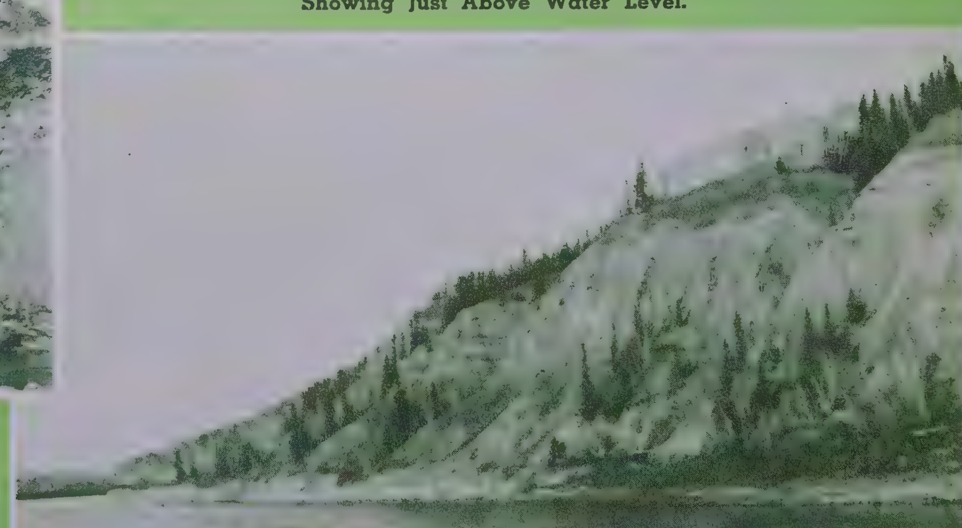


Diesel-powered Boat and Freight Barges.

S.S. Athabasca.

Water Front at Waterways.

Oil Sand Cutbanks on Athabasca River with Limestone Showing Just Above Water Level.



Close-up of an Oil Sand Cutbank.

Oil Sand Quarry at Bitumount.

Excavating Oil Sand.

Storage Hopper at Head of Separation Plant.

Devonian Limestone.

Limestone Exposures Along the Athabasca River.

Data

TRANSPORTATION

The Northern Alberta Railway connects Edmonton with Waterways on the Clearwater river. Waterways is 305 miles by rail from Edmonton and about three miles by road from McMurray. The railway service to Waterways is one passenger and freight train per week with two extra freight trains during the summer months.

The Northern Transportation Company takes freight from Waterways down the Athabasca river by diesel boats and barges during the season of navigation. Navigation starts about the first of May and ends during October.

The Canadian Pacific Airlines operates a daily (except Sundays) plane service from Edmonton to McMurray and on to Yellowknife and return. It also operates a weekly pontoon plane service from McMurray to points on the Athabasca river and Lake Athabasca. The plane leaves on Friday and returns Saturday. Planes can be chartered for special flights at McMurray.

McMURRAY

The population of McMurray is roughly 700. The Franklin Hotel — Mr. J. L. O'Coffey, Manager — offers comfortable room accommodation. Several restaurants provide meals. General stores and a pharmacy cater to the local needs. Direct telegraph communication is given by the Alberta Telegraph Service. The Canadian Army Signals operates by wireless to points throughout the north country. Bitumount, for instance, communicates through this station. Canadian Pacific Airlines has an office in McMurray. Its pontoon plane as well as other planes harbor at the mouth of the Clearwater river in the "sny".

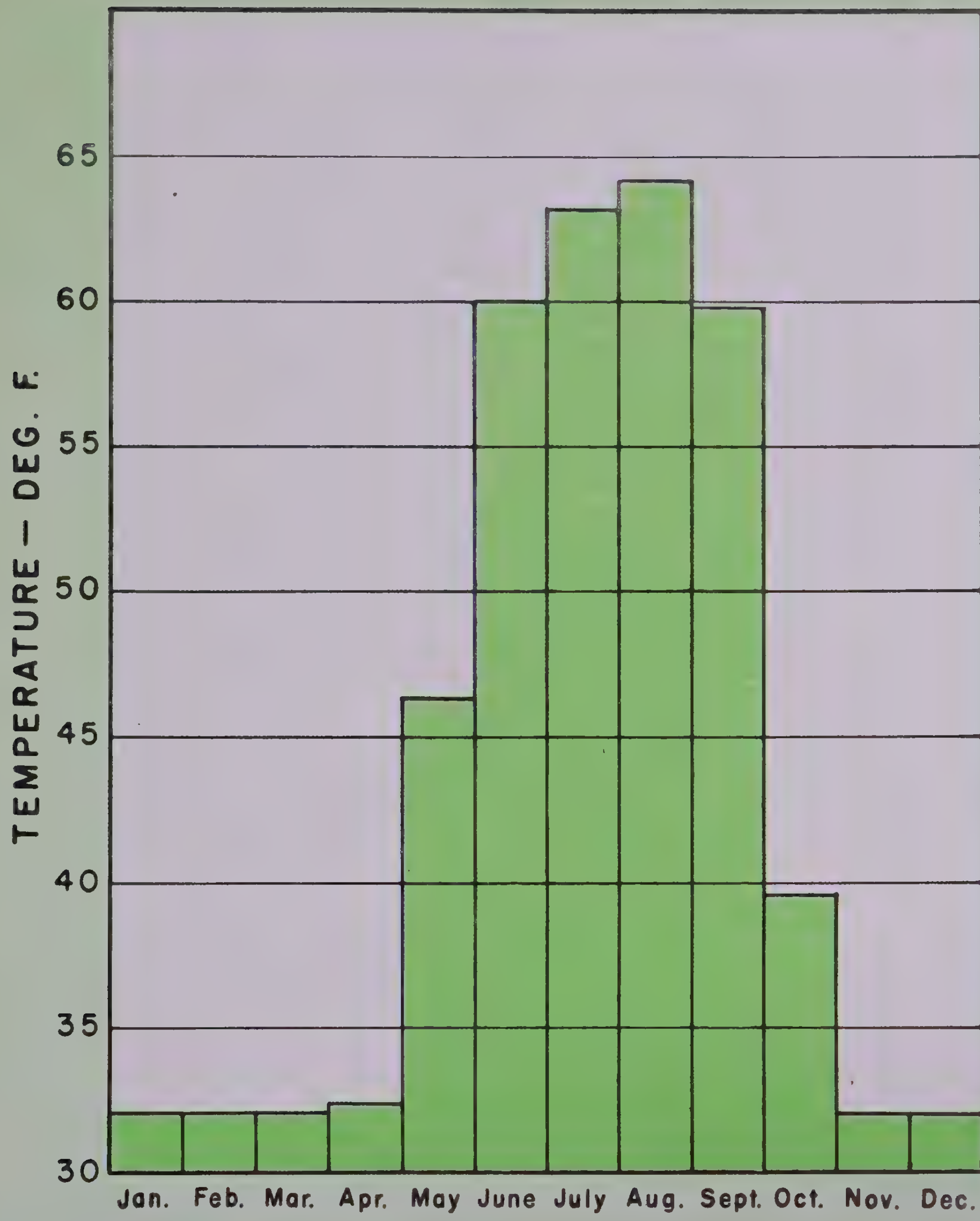
Waterways has a population of about 400. It is the terminal of the railway and the head of navigation for freighting down the Athabasca river. The freight shed and office of the Hudson's Bay Company are at Waterways; those of the Northern Transportation Company are nearby at the "prairie". A hotel and general stores take care of the needs of the town.

SUMMARY OF TEMPERATURES, PRECIPITATION AND SNOWFALL

Month.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
McMurray — 30-year Averages.													
Avg. Daily Max. °F.	1	15	28	49	64	71	76	72	61	46	24	6	43
Avg. Daily Min.	—20	—13	— 2	21	34	42	47	44	35	25	6	—13	17
Avg. Daily Mean	— 9	1	13	35	49	56	61	58	48	36	15	— 4	30
Avg. Precipn., in.	1.1	0.6	1.0	0.8	1.5	2.1	3.3	2.2	2.0	1.1	1.0	1.0	17.7
Avg. Snow-fall, in.	10.6	6.0	9.6	3.4	1.1	--	--	--	0.3	3.7	9.2	9.8	53.7
Embarass* — 7-year Averages.													
Avg. Daily Max. °F.	2	6	14	42	59	71	76	71	59	47	20	7	39
Avg. Daily Min.	—17	—17	—4	17	36	46	51	47	40	30	6	—11	19
Avg. Daily Mean	— 9	— 2	12	31	47	56	62	59	49	38	15	2	30
Avg. Precipn., in.	0.9	0.7	0.8	1.2	1.4	1.3	1.9	2.7	2.4	1.2	1.1	0.9	16.5
Avg. Snow-fall, in.	9.4	7.0	9.5	5.5	1.3	--	--	--	1.1	5.2	10.0	9.4	58.4

*Embarass is in the delta of the Athabasca river about 120 miles north of McMurray.

The temperature drops to —50° F. for short periods during December to February. It reaches 90° F. during the months of May to August.



ATHABASCA RIVER TEMPERATURES AT BITUMOUNT.

WATER ANALYSES

Analyses of Athabasca river water and of plant water taken from the separation cell of the hot-water separation plant of Bitumount (Filtered water.)

Sample	Athabasca River Water Parts per Million.	Water from Separation Cell Parts per Million.
Total soluble matter	194	845
Calcium carbonate	95	70
" sulphate	---	183
Magnesium carbonate	16	---
" sulphate	15	29
Sodium sulphate	15	170
" chloride	9	10
Silica	6	30
Organic matter	34	350
Total hardness	127	228
Carbonate "	114	70
Non-carb. "	13	158
pH.	8.0	8.2

The river water carries a variable amount of sediment depending on the volume of flow. It should be filtered for power plant and other uses. The sample was collected at medium flow.

The analysis of the separation plant water indicates the soluble salts contained in the oil sand at Bitumount.

STRATIGRAPHY

The stratigraphic succession in the Athabasca area is as follows:

Lower Cretaceous

Clearwater Formation: Grey and dark marine shales.

McMurray Formation: Bituminous and fine grained sands, in part cross-bedded and lenticular interstratified with clay and shales. Thin lignite seams and plant material.

Erosional disconformity.

Upper Devonian:

Waterways Formation: Shaly and massive fossiliferous limestone, in places overlain by residual limy clay of variable thickness.

NATURE OF THE BITUMINOUS SAND DEPOSIT.

The bituminous sand deposit, in the area of outcrops along the Athabasca river, has a thickness of about 200 feet. It is composed of beds of unconsolidated sand, silt and clay more or less impregnated with a very viscous, asphaltic oil. The sand beds are apparently the result of sedimentation under deltaic conditions, for they show much cross-bedding and lensing. Generally, the mechanical grading of the sand can be adequately expressed in terms of the 50 mesh sieve size and smaller. The percentage of material finer than 200 mesh varies from a few per cent to high percentages. Silt and clay occur as sand constituents, also as thin partings and as prominent beds. Close interbedding of sand, silt and clay is common. The oil content of the bituminous sand varies, mainly, with variations of silt and clay content. As a general rule, the sand becomes silty or clayey in nature as the content of material passing the 200 mesh sieve exceeds 20 per cent. As the sand becomes clayey the oil content decreases and the water content increases. Bituminous sand, as mined with less than 20 per cent of fine material, generally contains from 10 to 17 per cent of oil by weight and from 2 to 8 per cent of water.

The sand particles of the mineral aggregate of bituminous sand consist mainly of quartz. But as much as 5 per cent of these particles may be mica, rutile, ilmenite, tourmaline, zircon, spinel, garnet and pyrite. Lignite material is of common occurrence in parting planes. Large carbonized tree trunks have been found embedded in the bituminous sand beds.

Clay and sand cemented by pyrite into very hard, heavy flattish or rounded stones or nodules occur in some localities. Partings of a thin, friable sandstone with a carbonate ce-

menting occur in others. There is a quite persistent layer of hard sandstone with a siliceous cementing agent near the top of the formation. It varies from a few inches to a few feet in thickness.

The bitumen of the bituminous sand is a viscous asphaltic oil displaying considerable variation in properties. Its specific gravity at 25°/25°C ranges from 1·002 to 1·027. At ordinary temperature the lighter oils pour somewhat readily while the heavier ones can barely be said to pour. The content of 100 penetration asphalt ranges roughly from 65 to 80 per cent. The lighter hydrocarbons present correspond, in volatility, to the heavy end of gasoline. The lighter crude oils probably never contain more than 1 or 2 per cent of such hydrocabons and the heavier ones practically none at all. The sulphur content of the crude oil is 4 to 5 per cent. The crude oil is very susceptible to thermal decomposition, cracking being appreciable at 650° F. The products of simple refining of the crude are a few per cent of a high sulphur gasoline together with diesel oil, fuel oil and asphalt residuum.

Bituminous sand in its natural state of packing weighs about 125 lb./ft. Its coefficient of thermal conductivity is of the order of 0·0035 in c.g.s. units.* The specific heat of the mineral aggregate is 0·18 cal/gm while that of the oil is 0·35. The calorific value of the oil is 17,900 B.t.u./lb.

*0·0035 gm.cal./sec. cm.^{2} (°C.) = 25·8 B.t.u./hr. ft.^{2} (°F.).

BITUMINOUS SAND OIL ANALYSES AND VISCOSITIES

Analyses of Bituminous Sand Oils from Various Locations.

Location of Oil Sample.	Clearwater River Quarry	Abasand Oils Ltd. Quarry		Ells River	Bitumount	Mildred-Ruth Lakes	Explanatory Drill Holes 77-9-W. 4	95-5-W. 5
Ultimate Analysis—								
Carbon, %	83.6	83.3	83.0	83.3	83.3	83.4	83.4	82.9
Hydrogen	10.3	10.4	10.2	10.4	10.4	10.4	10.4	10.3
Sulphur	5.5	5.1	3.8	4.6	4.7	4.5	4.7	5.4
Nitrogen	0.4	0.4	0.5	0.4	0.4	0.5	0.6	0.5
Oxygen (diff.)	0.2	0.8	2.5	1.3	1.2	1.2	0.9	0.9
C/H ratio	8.1	8.0	8.1	8.0	8.0	8.0	8.0	8.1
Cal. Val. B.t.u./lb.	---	---	17.860	17.690	17.910	17.810	17.870	17.700
Sp. Gravity 77°/77°F.	---	---	1.022	1.007	1.007	1.010	1.006	1.022

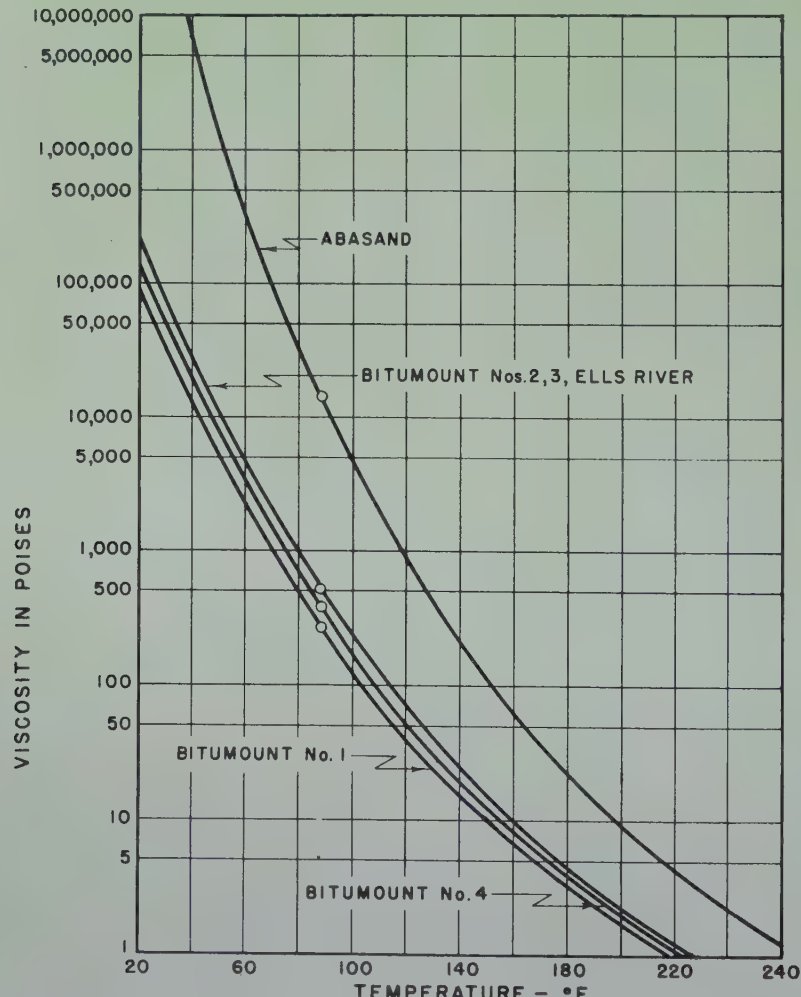
Twp. 77, R. 9, W. 4 is about 75 miles south of McMurray.

Twp. 95, R. 5, W. 5 is about 120 miles west of McMurray.

Comparison of Various Athabasca Bituminous Sands as Regards the Components of Their Bitumen

Bituminous sand*	Components			Asphaltenes as % of asphaltenes plus resins
	Asphaltenes, %	Resins, %	Oily constituents, %	
Bitumount 1A	20.1	25.0	54.9	44.6
" 1B	16.0	25.6	58.4	38.5
" 3	20.4	25.1	54.5	44.8
" 4	16.9	26.0	57.1	39.4
" 5	19.3	25.9	54.8	42.7
" 6A	19.4	24.8	55.8	43.9
" 6B	20.3	26.2	53.5	43.7
" 6C	22.8	29.0	48.2	44.0
Abasand	23.4	29.0	47.6	44.6

*The numbers Bitumount 1 to 6 inclusive represent different depths in the deposit at Bitumount; the larger the number the greater the depth. Solvents used—n-pentane, ethyl ether, benzene.



Viscosity-Temperature Relationship for the Oils occurring in Bituminous Sand Beds at Various Locations and in Beds at Different Elevations of the Same Location.

Results of Coking Tests on Crude Wet Oil from Hot Water Separation of Bituminous Sand Carried Out in the Fluidized Solids Continuous Retort of the National Research Council.

Run No.	B-37	B-39	B-40
Charge Stock: Bitumen, %	66.34	66.10	64.06
Water, %	30.16	30.80	32.98
Solids, %	3.50	3.10	2.96
Antifoam added ppm.	15	15	15
Charge Rate, lbs./hr.	12.7	14.3	16.9
Total Charge, lbs.	48.37	85.75	101.34
Still Temp. Deg. F.	983	997	1044
Burner Temp. Deg. F.	1396	1372	1490
Charge Temp. Deg. F.	69	72	69
Still Bed Depth, inches	30.0	30.6	30.7
Burner Bed Depth, inches	36	36	36
Still Gas Rate, ft./sec.	0.862	1.004	1.172
Burner Gas Rate, ft./sec.	0.99	0.99	1.00
Oil Yield, lbs.	27.14	46.09	52.59
Oil Yield, % by volume	88.56	84.35	83.43
Coke Yield, lbs.	2.59	4.59	5.28
Coke Yield, % by weight	8.1	8.1	8.1
Process Gas, cf/bbl. of bitumen	223	—	285
Process Gas, % by weight	4.92	—	6.18
Dust Yield: Burner Cyclone and Filter, lbs.	1.26	1.58	1.40
Still Cyclone (coke free), lbs.	0.51	1.55	1.71
In Distillate Oil, lbs.	0.12	0.31	0.81
Water Yield, lbs.	13.37	24.27	34.14

Mechanical Analysis of Bed Solids in Fluidized Solids Retort

Following Run No.	B36	B37	B39	B40
60 Mesh	10.0	10.3	10.8	9.1
60- 80 "	13.2	15.1	15.7	12.4
80-100 "	27.7	28.1	29.8	30.6
100-150 "	36.1	35.6	32.6	36.1
150-200 "	11.9	10.4	10.0	11.0
200-325 "	1.1	0.7	0.6	0.6
325 "	0.0	0.0	0.0	0.0

Laboratory Inspections of Distillates Produced by Coking Bituminous Sand Oil.

Properties	CONVENTIONAL COKING		FLUIDIZED SOLIDS COKING Total Distillate			Desulphurized (c) Blend of Abasand and Bitumount Distillates
	Debut. Gasoline	Coker Distillate	Abasand	Bitumount	M.-R. Lakes	
A.P.I. at 60° F.	51.9	16.6	15.5	16.6	14.1	26.2
Sp. Gr. at 60° F.	0.7715	0.9554	0.9626	0.9554	0.9718	0.8973
Total Sulphur wt. %	1.86	4.04	4.12	4.01	3.83	0.26
Mercaptan Sulphur wt. %	0.226					
Nitrogen wt. %			0.27	0.22	0.27	
Con. Carbon Resid. wt. %			7.9	5.7	7.85	1.22
B.S. & W. vol. %		0.1	0.05	0.15	1.5	
Tar Acids vol. %		0.2	0.8	2.1		
Tar Bases vol. %		0.1	0.35	0.6		
Bromine No.	80	47	54	45	49	10
Olephin Content wt. %	55				89	
Aromatic Content wt. %	12					
Pour Point Deg. F.		20	30	30	25	35
Viscosities—						
Saybolt Univ.						
Secs. at 210° F.						34.2
Secs. at 100° F.		70.8	200	173	321	55.3
Kinematic, Centistokes						
at 210° F.						
at 100° F.		13.32	43.17	37.15	69.37	2.377
at 32° F. (Est.)		90	540	430		8.984
Octane Numbers—						
F-2, Clear (Unisol Sweet)	69.1					
F-2, 2.5cc TEL/Gal.	74.0					
Ash Content p.p.m.			176	315	660	58

Distillation	Atmos.	Atmos.	Atmos.	Vac.	Atmos.	Vac.	Atmos.	Vac.	Atmos.	Vac.
I.B.P. Deg. F.	126	443	185	122(a)	224	100(a)	181	98(a)	200	108(a)
5%	165	466	285	246(a)	365	321(a)	362	312(a)	294	250
10%	186	486	400	375(a)	450	421(a)	500	462(a)	364	330(a)
30%	232	550	617	662	610	651	633	702	537	580
50%	275	621	658	776	668	776	679	806	634	681
70%	315	690	694	886	703	877	705	909	720	751
90%	358	715	720	960(b)	---	956(b)	726	972(b)	760	857
E.P. Deg. F.	400	760	---	---	---	---	---	---	---	---
% Recovered	98.5	97.5	90.5	82.0	92.5	83.0	91.0	86.5	98.5	97.5
% Bottoms	1.0	---	---	18.0	---	17.0	---	13.5	---	2.5
Wt. % Coke	---	2.5	9.3	---	7.5	---	9.0	---	1.3	---
% at 400° F. by Hempel	---	---	---	11.3	---	8.6	---	7.0	---	15.0

(a) Atmospheric Hempel. (b) 80% Point. (c) Desulphurization by mild hydrogenation.

The Hot Water Washing Method

For the Recovery of Oil from the Alberta Tar Sands*

By K. A. CLARK
Research Council of Alberta

Washing bituminous sand with water, especially hot water, is an obvious approach to the problem of separating the oil from it. The method has been used in many countries throughout the world. S. C. Ells has reviewed its history (1). The bituminous sands of Alberta are particularly amenable to treatment by hot water. The application of hot water washing as applied to this material has been a subject of study by the Research Council for many years.

The hot water washing of Athabaska bituminous sand, as practised by the Research Council of Alberta can be described most simply by use of a diagrammatic drawing of its laboratory separation plant, Fig. 1. This plant is used for studying the various factors involved in the process and is designed for batch feed. A batch of bituminous sand is placed in the steam-jacketed mixer, 1, along with sufficient water to give the pulp a water content of about 12 percent. Mixing is continued for fifteen minutes and the temperature is raised to 185°F. The final pulp is of the consistency of a thin brick mortar. It will pour but there is no excess of water in it. When ready, the pulp is dumped into the feeder, 2, which passes it into the stream of hot water circulating through the rest of the apparatus.

Circulating the hot plant water is a distinguishing feature of the Research Council of Alberta hot water process. In the laboratory plant a sand pump takes a stream of water and sand from the boot of the separation cell, 4, and delivers it to the settling cone, 7. The sand is trapped in the cone and the water overflows into the constant flow regulator, 6. A pipe, hidden in Fig. 1, takes the water to the heater, 5, where its temperature is restored to 185°F. or somewhat higher. It then passes on to the pulp-flooding cell, 3, which it enters at opposite sides in two streams arranged to cause a pronounced turbulence in the cell. The water overflows from this cell into the separation cell completing the circuit.

The hot bituminous sand pulp drops from the feeder, 2, into the turbulent hot water in the pulp-flooding cell, 3. It is promptly dispersed into sand and oil flecks that are small but of varying size. All but the very small oil flecks become associated with water vapor or air and form oil bubbles. Sand and oil bubbles are swept on into the separation cell where, under comparatively quiet conditions, the sand sinks and the oil floats to the surface as a froth. Clay, silt and the finest of the oil flecks remain suspended in the plant water. The sand is carried to the boot of the cell by a screw conveyor and is picked up by the suction of the sand pump. The oil froth is skimmed from the water surface of the cell.

The flooding of the pulp is a critical operation. Strong agitation is needed to cause the pulp to disperse. But the agitation must not be accompanied by aeration. The penalty for aeration is the loading of the oil froth with sand. The arrangement indicated in Fig. 1 works quite well. It produces an oil froth containing about 4 percent of sand, silt and clay. If no care is exercised in avoiding aeration, a froth with 25 percent sand content will result. The mineral matter content of the froth can be kept low by proper design of the flooding arrangement. But the water content is always high — generally between 30-35 percent.

An obvious matter of interest is where the oil that is introduced into the separation plant in the bituminous sand feed goes in passing through the plant. The answer to this question is given by the data of Tables I and II. These data also give an indication of the variable composition of bituminous sand and the bearing of these variations on separation results.

The factor that has the most potent effect on separation results is the content of very fine mineral matter in the bituminous sand — the clay content, using this term in a broad sense. (2) Table 1 shows clay contents of bituminous sand

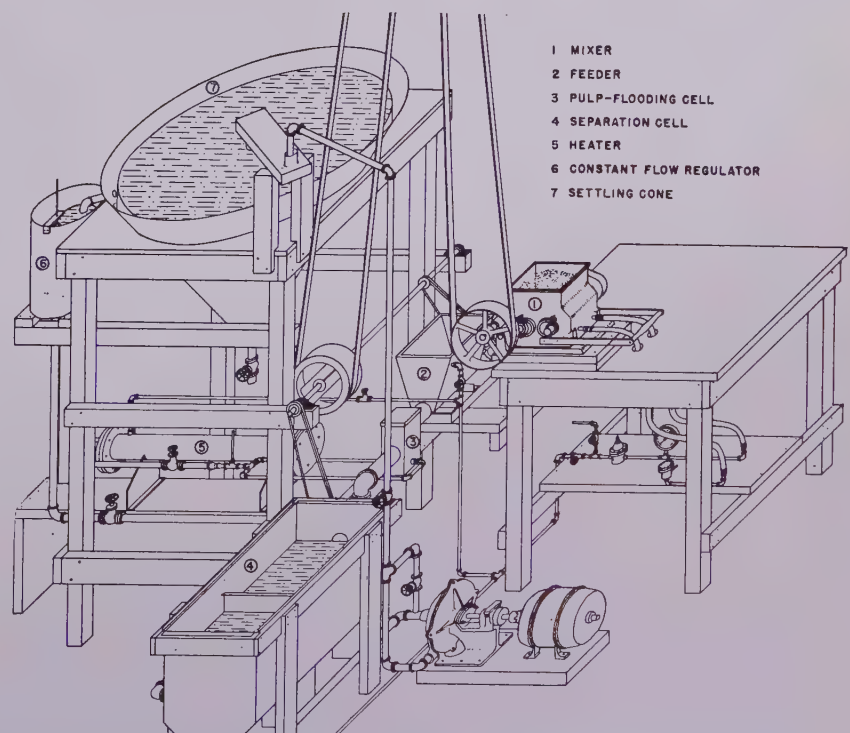


Fig. 1—Isometric drawing of laboratory hot water separation plant.

Reprinted from CANADIAN OIL AND GAS INDUSTRIES, September, 1950

from a number of locations. Five of them have from 3.5 to 5.7 percent of very fine mineral matter but this constituent increases to 7.4 percent in the Ells River sand and to 16.8 percent in the Bitumount sand to which clay was added. Table II shows that the yield of oil in the hot water separation of these bituminous sands (percent of total oil found in oil froth) was from 76.1 to 80.3 percent for the five sands with clay contents between 3.5 to 5.7 percent but dropped sharply to 63.4 and 44.2 percent in the case of the Ells River sand and of the Bitumount sand to which clay was added. This and other studies have shown that some clay in the bituminous sand is necessary for effective hot water separation but that more than this necessary amount reduces the yield of oil in the form of oil froth. Clay either as a constituent of bituminous sand or as partings between bituminous sand beds is the main seat of trouble. High clay content is accompanied by low oil content (3, 4, 5). And the high clay content reduces the yield of oil from hot water separation. It will probably prove to be a detrimental factor in any method of processing.

The "oil content of clay in tailings and in plant water", Table II, was obtained by washing finely divided material from the sand tailings and then settling out this fine material as well as that suspended in the plant water. This fine material was dried and then analysed for oil content. It is wrong to conclude, from the analyses, that the oil is adsorbed onto the clay. What happens is that some of the oil in the bituminous sand pulp goes into the form of very small oil flecks that fail to float as froth, on flooding the pulp with water, and that stay in suspension in the plant water along with the clay. These tiny oil flecks have a settling rate comparable to that of the clay and, consequently, they settle out with the clay. It is seen, from Table II, that the proportion of the oil that forms tiny flecks and becomes dispersed in the plant water increases with increasing clay content in the bituminous sand. This is why a high clay content in the bituminous sand decreases the yield of oil as oil froth. Much of the dispersed oil can be recovered in a secondary recovery operation consisting of passing the clay and oil flecks in a water suspension through a flotation cell.

The hot water separation process, then, has the following features. When the bituminous sand is mixed and heated to a pulp with about 10 percent of its weight of water, the oil goes into the form of small flecks lying among clean sand grains. The formation of oil flecks is closely associated with the clay content of the bituminous sand. The oil flecks vary in size. As the clay content increases, the proportion of the oil that goes into very small oil flecks increases. When the pulp is flooded with hot water, the oil flecks that are larger than some critical size become associated with water vapor or air and rise to the surface as an oil froth. Smaller oil flecks fail to float and remain dispersed in the plant water. The formation of the oil froth is essential for the primary recovery of oil.* But, since oil bubbles float mineral matter, more than enough frothiness to cause the oil to rise does no good and does harm by loading the froth with sand particles. Most of the very small oil flecks can be recovered by a subsequent operation consisting of passing the suspension of clay and fine oil flecks, freed of sand, through a flotation cell. The significance of secondary oil recovery increases as the clay content of the bituminous sand increases.

The Government of Alberta has built and operated a pilot separation plant in the bituminous sand area on the Athabaska river (6). There have

*The specific gravity of the oil in Athabaska bituminous sand is slightly greater than one.

Table I—Compositions and Sieve Analyses of Bituminous Sands Used in Separation Runs for Accounting for All Oil

Bituminous Sand	Bitumount No.2	Bitumount No. 4	Abasand	Bitumount No. 3	Bitumount No. 1	Ells River	Bitumount No. 3 + Clay*
Composition:							
Water..................%	1.0	4.5	3.1	3.1	2.1	4.5	
Mineral matter..........%	84.7	84.8	81.7	81.4	82.8	84.1	
Oil (by difference).......%	14.3	10.7	15.2	15.5	15.1	11.4	
Sieve analysis of mineral matter after ignition:							
Retained							
on 50 mesh........%	11.0	41.2	0.3	13.0	18.3	0.2	
on 80 mesh........%	46.8	34.3	3.3	41.0	49.9	3.5	
on 100 mesh........%	20.8	10.2	17.9	20.0	13.3	14.5	
on 200 mesh........%	16.4	9.0	69.9	18.5	11.0	61.0	
Passing 200 mesh........%	5.0	5.3	8.6	7.5	7.5	20.8	
Mineral matter still suspended in water after 1 minute settling..........%	3.5	4.0	4.0	5.7	5.7	7.4	16.8 (calc.)

* The clay added was from a clay parting occurring in the bituminous sand formation.

Table II—Distribution of Oil Between Oil Froth, Sand in Tailings, Clay in Tailings and Plant Water in Separation Runs to Account for All Oil

Bituminous Sand	Bitumount No.2	Bitumount No. 4	Abasand	Bitumount No. 3	Bitumount No. 1	Ells River	Bitumount No. 3 + Clay
Composition of oil froth:							
Water..................%	35.4	37.8	27.7	35.7	36.4	36.5	35.4
Mineral matter..........%	4.5	2.8	4.7	3.9	5.8	3.9	3.8
Oil (by difference).......%	60.1	59.4	67.6	60.4	57.8	59.6	60.8
Oil content of sand tailings (dry basis)..............%	0.50	0.41	0.44	0.27	0.56	0.25	0.41
Oil content of clay in tailings and in plant water (dry basis)..................%	52.8	43.5	47.4	44.8	41.8	42.2	35.0
Percent of total oil found in:							
Oil froth................%	78.6	76.1	77.1	80.3	79.4	63.4	44.2
Sand tailings............%	2.7	3.0	2.1	1.3	2.9	1.6	1.2
Clay in tailings and plant water..............%	13.3	17.1	15.4	14.9	12.1	31.4	52.4
Miscellaneous...........%	2.7	1.6	4.1	1.6	2.2	2.1	1.6
Total oil accounted for.......%	97.3	97.8	98.7	98.1	96.6	98.5	99.4

(Alberta Government Photo)

Excavating bituminous sand in the Bitumount quarry (above).

been former plants. The Research Council of Alberta built and operated a very small one on the Clearwater river in 1929-30. The International Bitumen Company had a plant fifty miles downstream from McMurray on the Athabaska river at a site that was named Bitumount. The plant was active from 1930 to 1944. The plant and lease were acquired by Oil Sands Ltd. in 1942. The Abasand Oils Ltd. built a plant in Horse River valley near McMurray, starting in 1936. The plant was active until 1943 when it was taken over by the federal government for experimental purposes. It was operated by the federal government until 1945 when work was brought to an end by a disastrous fire. All these plants separated oil from the bituminous sand by washing with hot water. There was no difficulty about producing oil. But because of mechanical difficulties due to makeshift equipment or difficulties inherent in pioneer efforts and because of fires, the public impression was that the hot water process was unworkable. The provincial government decided that it was in the interest of the future of its bituminous sand resource to build a separation plant and to demonstrate that all that was necessary for successful operation of the hot water process was good design and equipment.

The government plant was built at Bitumount. At the start of the project it was a co-operative effort between Oil Sands Ltd. and the Government of Alberta. Subsequently the government took complete control. The plant consisted of a separation unit, a dehydrating unit and a refinery. The separation unit was designed, in principle, on the results of studies by the Research Council of Alberta. In regard to mechanical design, use was made of experience gained in former plants. The separation unit was the one of main interest. The dehydration unit and refinery were necessary accessories for making fuel oil to generate heat and power. The method used in the dehydration unit for ridding the crude separated oil of its high water content was not regarded as a good one but it was the only sure method available (7). The refinery recovered the diluent used in the dehydrating and produced fuel oil for the power plant.

The flowsheet of the Bitumount plant is shown in Fig. 2. The features of the Research Council of Alberta procedure, namely bituminous sand pulp of about 12 percent water content, avoidance of aeration in flooding the pulp and circulation of the plant water, were used. The Bitumount plant performed well. The mineral matter content of the oil froth was between 4 to 8

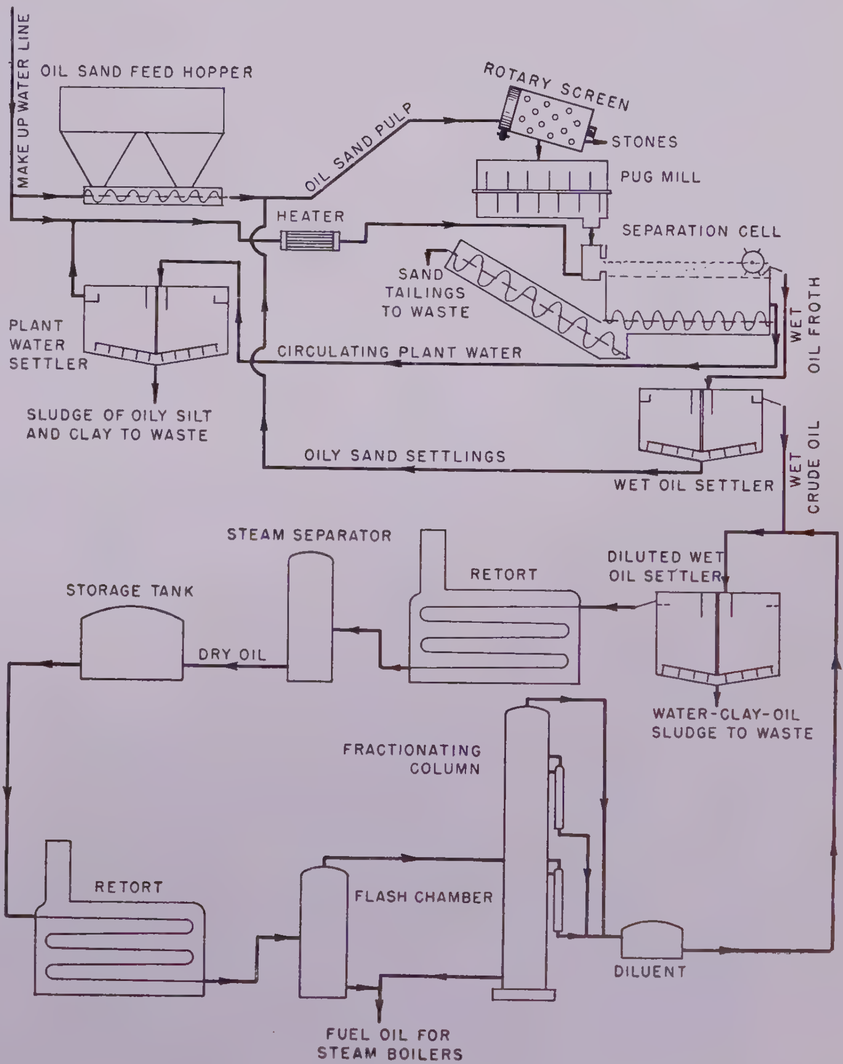


Fig. 2—Flowsheet of pilot bituminous sand plant of Bitumount.

percent as in laboratory work. The yield of oil as froth was better than in the laboratory; it was around 90 percent. The reason for the better yield was that the large plant worked on bituminous sand that was freshly mined. It has been known that bituminous sand deteriorates, from the separation standpoint, after mining and as it stands in storage (2). The plant water settler removed fine mineral matter and fine oil flecks from the plant water effectively. The underflow from the settler could have been put through a flotation cell for secondary recovery of oil but this was not done. When, for various reasons, the overflow from the plant water settler was dirty and the plant water became heavily charged with suspended matter, no effect on the yield or quality of the oil froth was noticeable. Laboratory study had indicated that this would be so but the batch operations did not give opportunity for making sure about the point.

An important feature of the hot water process as carried out at Bitumount is that the heat and power requirements pretty well balance. Power is necessary for pumping water to the plant as a whole as well as for driving machinery in general. By exhausting steam from power generation at a few pounds pressure, the exhaust steam available does all the heating required. Use of heat, of course, reduces the power needed for handling the bituminous sand and the oil recovered from it.

Three methods for recovering oil from the Athabaska bituminous sands have been described in this journal (8). There are several approaches to excavating the sands. The oil industry has many methods for refining crude oils. There is thus no apparent gap in the necessary operations for taking bituminous sand from the deposit and processing it into marketable products. A logical step, now, is to set down a complete sequence of operations, from mining to marketing, and to examine it from both the technical and economic standpoints. In fact, the study should include the examination of alternative sequences in order to determine which is the most advantageous. Such a survey would give two useful results. It would give the answer to a question that interests everybody, namely, whether bituminous sand development belongs to this generation or to a future one. And, it would reveal where further technical study is required. The Government of Alberta has authorized this survey of possibilities for bituminous sand development. The survey is now under way.

References

(1) Ells, S. C., BITUMINOUS SANDS OF NORTHERN ALBERTA. Report 632, Mines Branch, Department of Mines, Ottawa. (1926).

(2) Clark, K. A. and Pasternack, D. S., THE ROLE OF VERY FINE MINERAL MATTER IN THE HOT WATER SEPARATION PROCESS AS APPLIED TO ATHABASKA BITUMINOUS SAND. Report 53, Research Council of Alberta, Edmonton, Alberta. (1949).

(3) Clark, K. A. and Blair, S. M., THE BITUMINOUS SANDS OF ALBERTA. Report 18, Part I, Research Council of Alberta, Edmonton. (1927).

(4) Ells, S. C., CORE DRILLING BITUMINOUS SANDS OF NORTHERN ALBERTA, Investigations of the Mineral Resources and the Mining Industry, 1928. Mines Branch, Department of Mines, Ottawa.

(5) DRILLING AND SAMPLING OF BITUMINOUS SANDS OF NORTHERN ALBERTA, Vol. II, Results of Investigations, 1942-1947. Bureau of Mines, Department of Mines and Resources, Ottawa.

(6) Adkins, W. E., REPORT TO THE BOARD OF TRUSTEES ON THE OIL SANDS PROJECT FROM INCEPTION TO DEC. 31, 1948. Government of Alberta, Edmonton Adkins, W. E., REPORT TO THE BOARD OF TRUSTEES ON THE ALBERTA GOVERNMENT OIL SAND PROJECT FROM JAN. 1, 1948 TO DEC. 31, 1949. Government of Alberta.

(7) Clark, K. A. and Pasternack, D. S., ELIMINATION OF WATER FROM WET CRUDE OIL OBTAINED FROM BITUMINOUS SAND BY THE HOT WATER WASHING PROCESS. Can. Chem. Process Ind. Nov. 1947.

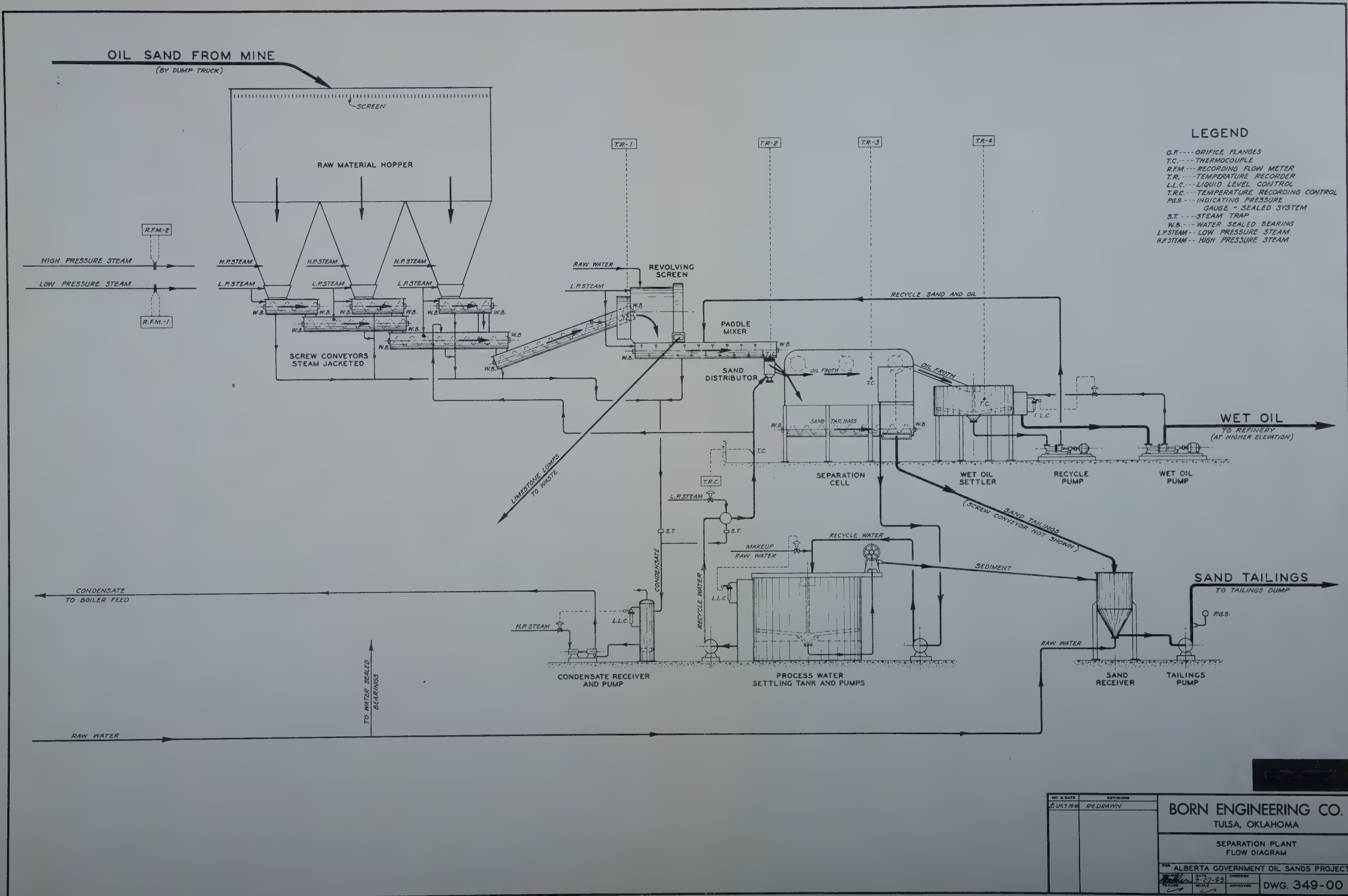
(8) Gishler, P. E. and Peterson, W. S., THE FLUIDIZED SOLIDS TECHNIQUE APPLIED TO THE PRODUCTION OF OIL FROM ALBERTA BITUMINOUS SAND. Can. OIL & GAS Ind. Nov. 1949.

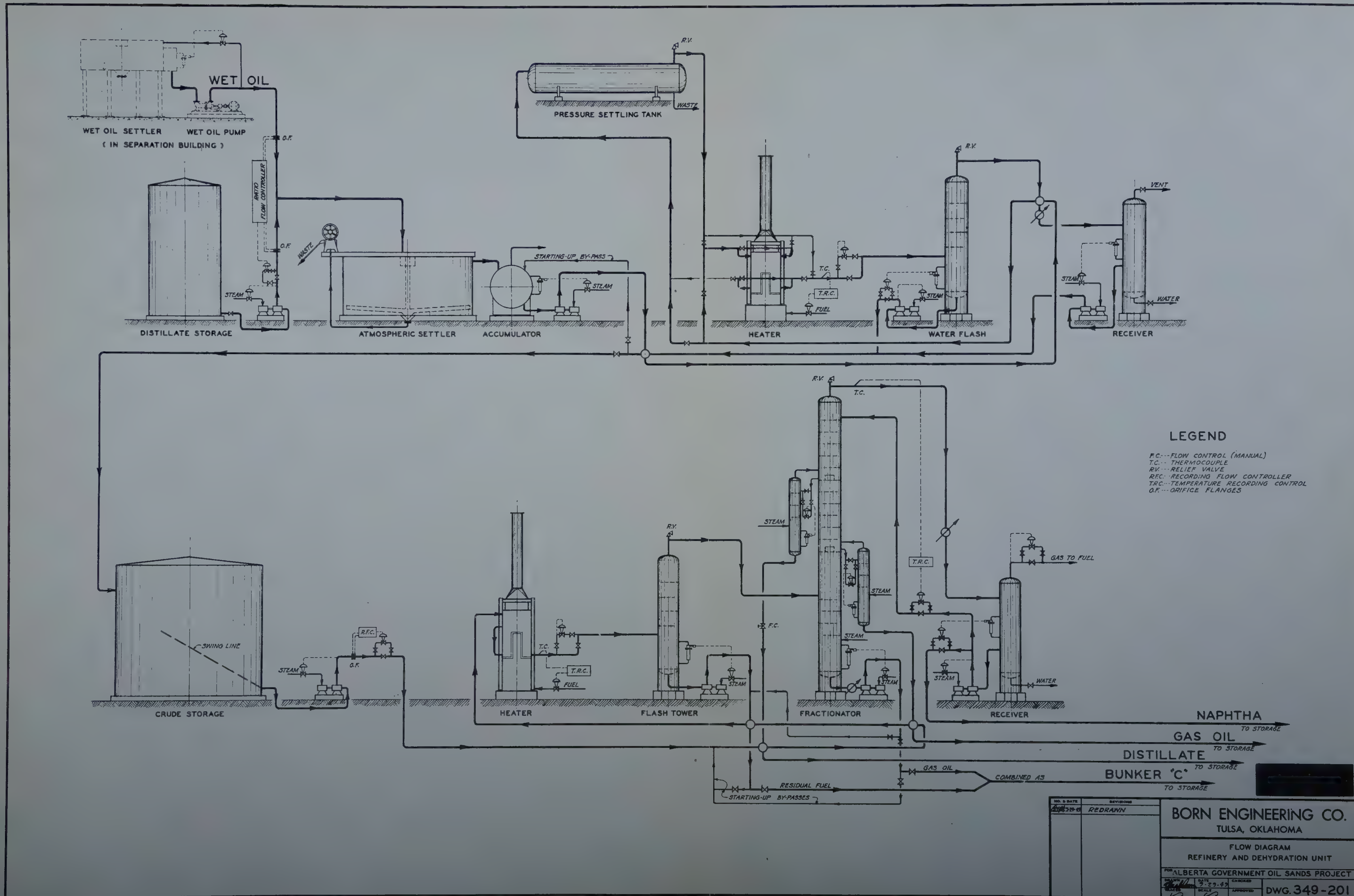
(8) Warren, T. E., Burrough, E. J., and Djingheuzian, L. E., THE COLD WATER METHOD APPLIED TO SEPARATION OF OIL FROM ALBERTA BITUMINOUS SAND. Can. Oil & Gas Ind. Jan. 1950.

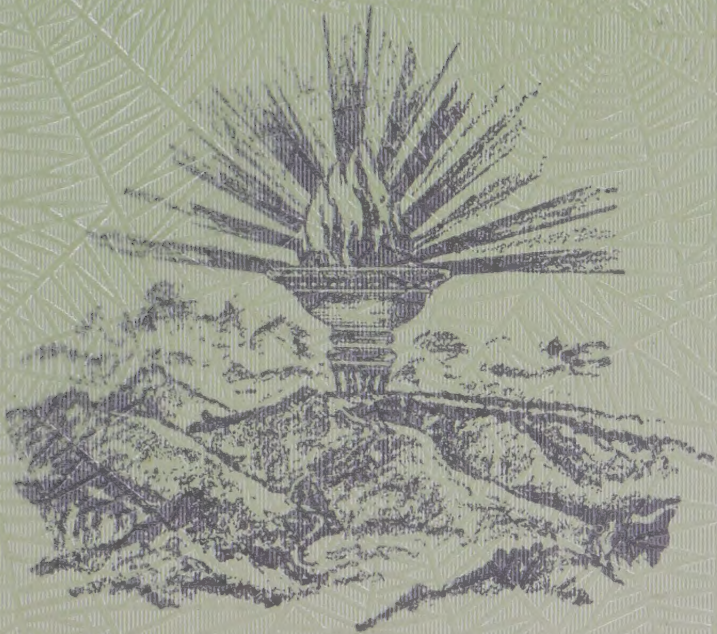
Dehydration and Refining Units at Bitumount.

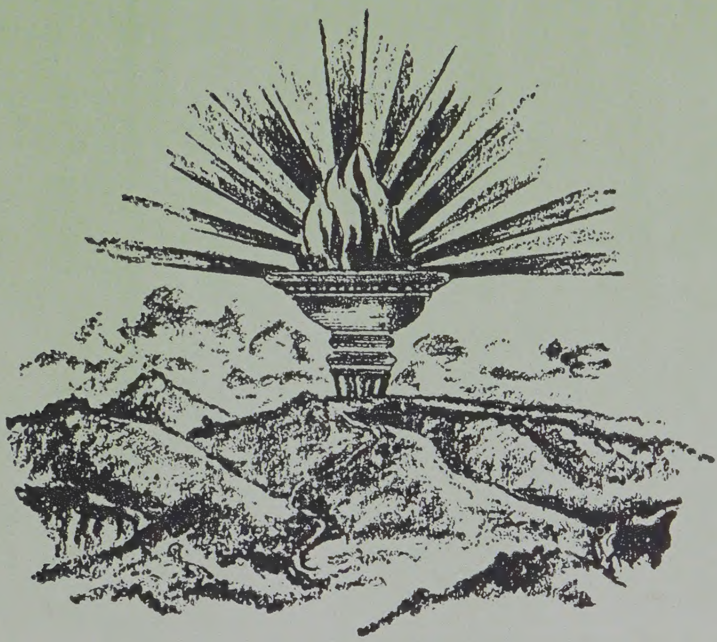
NOTES

NOTES


OIL SAND FROM MINE
(BY DUMP TRUCK)
SCREEN
RAW MATERIAL HOPPER
T.R.-1
T.R.-2
T.R.-3
T.R.-4
LEGEND
O.F.----ORIFICE FLANGES
T.C.----THERMOCOUPLE
R.F.M.---RECORDING FLOW METER
T.R. ----TEMPERATURE RECORDER
L.L.C.---LIQUID LEVEL CONTROL
T.R.C.---TEMPERATURE RECORDING CONTROL
P.G.S.---INDICATING PRESSURE GAUGE - SEALED SYSTEM
S.T.----STEAM TRAP
W.B.---WATER SEALED BEARING
L.P.STEAM-- LOW PRESSURE STEAM
H.P.STEAM-- HIGH PRESSURE STEAM
R.F.M.-2
HIGH PRESSURE STEAM
LOW PRESSURE STEAM
R.F.M.-1
H.P.STEAM
L.P.STEAM
W.B.
SCREW CONVEYORS
STEAM JACKETED
RAW WATER
REVOLVING SCREEN
PADDLE MIXER
RECYCLE SAND AND OIL
SAND DISTRIBUTOR
OIL FROTH
SAND TAILINGS
T.C.
L.L.C.
WET OIL
TO REFINERY
(AT HIGHER ELEVATION)
SEPARATION CELL
WET OIL SETTLER
RECYCLE PUMP
WET OIL PUMP
LIMESTONE LUMPS TO WASTE
T.R.C.
S.T.
SAND TAILINGS
(SCREW CONVEYOR NOT SHOWN)
RECYCLE WATER
MAKEUP RAW WATER
SEDIMENT
CONDENSATE
CONDENSATE TO BOILER FEED
SAND TAILINGS
TO TAILINGS DUMP
P.G.S.
CONDENSATE RECEIVER AND PUMP
PROCESS WATER SETTLING TANK AND PUMPS
SAND RECEIVER
TAILINGS PUMP
TO WATER SEALED BEARINGS
RAW WATER
NO & DATE
REVISIONS
REDRAWN
BORN ENGINEERING CO.
TULSA, OKLAHOMA
SEPARATION PLANT
FLOW DIAGRAM
FOR ALBERTA GOVERNMENT OIL SANDS PROJECT
DRAWN
DATE
9-27-49
CHECKED
TRACED
SCALE
APPROVED
DWG. 349-00


WET OIL
WET OIL SETTLER
WET OIL PUMP
(IN SEPARATION BUILDING)
O.F.
RATIO FLOW CONTROLLER
O.F.
WASTE
STEAM
DISTILLATE STORAGE
ATMOSPHERIC SETTLER
STARTING-UP BY-PASS
STEAM
ACCUMULATOR
R.V.
PRESSURE SETTLING TANK
WASTE
HEATER
T.C.
T.R.C.
FUEL
R.V.
STEAM
WATER FLASH
VENT
STEAM
WATER
RECEIVER
R.V.
T.C.
STEAM
STEAM
STEAM
STEAM
T.R.C.
GAS TO FUEL
R.V.
F.C.
SWING LINE
STEAM
R.F.C.
O.F.
T.C.
T.R.C.
FUEL
STEAM
STEAM
WATER
CRUDE STORAGE
HEATER
FLASH TOWER
FRACTIONATOR
RECEIVER
NAPHTHA
TO STORAGE
GAS OIL
TO STORAGE
DISTILLATE
TO STORAGE
BUNKER "C"
TO STORAGE
GAS OIL
COMBINED AS
RESIDUAL FUEL
STARTING-UP BY-PASSES
[redacted]
LEGEND
F.C.---FLOW CONTROL (MANUAL)
T.C.-- THERMOCOUPLE
R.V.---RELIEF VALVE
R.F.C.--RECORDING FLOW CONTROLLER
T.R.C.---TEMPERATURE RECORDING CONTROL
O.F.---ORIFICE FLANGES
NO. & DATE
REVISIONS
REDRAWN
BORN ENGINEERING CO.
TULSA, OKLAHOMA
FLOW DIAGRAM
REFINERY AND DEHYDRATION UNIT
FOR ALBERTA GOVERNMENT OIL SANDS PROJECT
DRAWN
DATE
9-29-45
CHECKED
TRACED
SCALE
APPROVED
DWG. 349-201





PUBLISHED BY AUTHORITY
GEORGE A. CLASH, AGENT
BOARD OF TRUSTEES,
OIL SANDS PROJECT

EDMONTON: Printed by A. Shnitka, King's Printer for Alberta, 1951.